Climate induced changes along the West Antarctic Peninsula: Where have we been? Where are we going?
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Acknowledgements to past LTER PIs: Ray Smith, Barbara Prezelin, Robin Ross, Langdon Quetin, Dave Karl, Maria Vernet, Eileen Hoffman, John Klinck
A rough day in the office
2009 represented the beginning of the next 6 year effort of the LTER. The grid has expanded to the south.
The central hypothesis when the LTER began was that sea ice timing and magnitude structure the productivity and composition of the Antarctic ecosystem. The ice dynamics are driven by large-scale interactions of the atmosphere and ocean.
The WAP peninsula is experiencing the largest winter warming on Earth

Larson-B ice shelf after its collapse
Thanks to BAS & A. Clarke

Air temperature increases over the peninsula
Sea ice duration drops

Mean Winter Temperatures

Black is British Faraday & Ukraine Vernadsky Station
Red is US Palmer Station

Slope (Faraday) = 0.98 degC per decade
Slope (Palmer) = 1.15 degC per decade
In 2008 the Wilkes Ice Sheet followed the Larson Ice Shelf and began to collapse
Melt pools on surface of King George VI Sound
(from a BAS twin otter, January 2004)
Seasonal ice has declined over the few decades resulting to a climate migration to the South.

Key Implications:
Regional shifts in the sea ice has major ecological implications.
Palmer Station in the present

photo by Bill Fraser
Plants at Palmer Station, the greening of Antarctica
Interannual variability is complex due to interacting influence of the Southern Annular Mode and El Niño/La Nina

Stammerjohn et al. 2006
Heat input from Antarctic Circumpolar Current (ACC - world’s largest ocean current = ~30,000 Niagara Falls). The heat is driven onto the shelf by intensification of upwelling-favorable winds.

The WAP is the only location in the Antarctic where the ACC is adjacent to the shelf break. The ACC is Antarctica’s warmest water.
Upwelling favorable winds result in Ekman mass transport offshore
Heating on the WAP is driven by circulation and intrusion of the ACC onto the WAP continental shelf. Using decadal averages of the scant data, there was a jump after the year 2000.

\[
\begin{align*}
1930-1989 \text{ Mean } Q_{\text{slope}} &= (2.98 \pm 0.16) \times 10^5 \\
1990-2004 \text{ Mean } Q_{\text{slope}} &= (3.83 \pm 0.07) \times 10^5 
\end{align*}
\]

~0.7°C warming of 300 m column of water below winter mixed layer

Thanks to Doug Martinson
Palmer time series: Phytoplankton show large interannual variability.
No strong correlations to seasonal meteorological data
Weak inverse relationship to the wind forcing the week prior
NCP from LMG0801 and LMG0901 is negatively correlated with the MLD.

NCP from LMG0801 significantly correlated with averaged chl concentration in the mixed layer.

Huang & Bender
The decadal changes have resulted changes in the phytoplankton

The changes driven by a decline in sea ice, wind and sun
A 15-year time series of radiocarbon measurements also suggest a North & South gradient.
When chlorophyll is high, phytoplankton cells are big and are largely diatoms.

Montes Hugo et al. 2009
Change in biomass impact on biogeochemistry
Export fluxes are episodic, show seasonal peaks, and appear to have changed
What regulates phytoplankton blooms in this region?
Who will dominate the warmer WAP?

- Proportion of total chlorophyll a associated with cryptophytes vs. proportion of total chlorophyll a associated with diatoms
- Temperature (°C) vs. Salinity

Moline et al. GBC 2004
Cryptomonas cryophila

Thalassiosira antarctica

Corethron criophilum

Palmer Cryptophytes --> $8 \pm 2\mu m$

SEM Micrographs from McMinn and Hodgson 1993

Cryptomonas cryophila

100\mu m

10\mu m
**A general feature in the warming WAP?**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Salinity (ppt)</th>
<th>Density (σ)</th>
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<tbody>
<tr>
<td><img src="image" alt="Graph" /></td>
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</tbody>
</table>

**Location**
- South Shetland Islands
- Weddell-Scotia-Bellingshausen Confluence Areas
- Ellis Fjord
- Bransfield Strait

**Reference**
- Vilafañe et al., 1995;
- Kang, S-H et al., 1997;
- Kang, J-S et al., 1997
- Lancelot et al., 1991;
- Nothig et al., 1991
- Tréguer et al., 1991;
- Buma, 1992;
- Mura et al., 1995;
- Kang and Lee, 1995;
- Aristegui et al., 1996
- McMinn and Hodgson, 1993
- Kang and Lee, 1995;
- Kang et al., 1995

**Historical Data**
- Anvers Island
- Signy Island

- Krebs, 1983
- Whitaker, 1982
CO₂ uptake varies with phytoplankton community

Montes Hugo in prep
Zooplankton are dominated by krill or salps

Krill greatest biomass of any animal on earth
McClatchie and Boyd 1983

Boyd et al. 1984

Quetin and Ross 1985

Phytoplankton Size (µm)
From Loeb et al., 1997
Is there an impact on higher trophic levels?
One focus idea of the LTER is testing, is that system is undergoing climate migration. We have structured sampling around the major Adelie penguin breeding areas along the peninsula.

To be expanded by NASA grant awarded in Dec.
The Adelie penguins feed during the daylight hours and are visual feeders and need to get back to the rookeries by nightfall, limits the foraging area to around ~50 kilometers. The penguins feed at the base of the chlorophyll maximum where water is clear.

Glider leaks, emergency recovery and repair (yikes!)

Radio-tagged foraging depths of Adelie penguins

Solar quenching of Chlorophyll fluorescence
Changing diets for the Adelie penguins

1994-present

1995-present

A climate gradient along the peninsula; Warm, moist maritime conditions migrating south

Warmer moister

Cooler drier
NORMALIZED OTOLITH ABUNDANCE IN DIET SAMPLES

YEAR

Silverfish

Lanternfish

If that was not enough, warmer temps leads to more moisture and more snow. Breeding failure........
Where are we headed? We need your help to communicate what we find as it happens.
2009 represented the beginning of the next 6 year effort of the LTER. The grid has expanded to the south.
2009 LTER heads to Charcot to see if a penguin colony exists as predicted
Phytoplankton Dynamics

Over thirty years, we see large changes in phytoplankton productivity (overall decline)

Over decade trends are less clear

Annual Rate of Chlorophyll Change (mg/m³) 1996–2009

change on satellite-derived chlorophyll a (dChla, mg m⁻³)
Development of GAM model for penguins rookeries. We analyze sea ice, wind, temperature, and chlorophyll in and around penguin rookery areas in WAP to determine which variables are most important for modeling the rookery environment.

10 year analysis annual trends

- Ice decline
- Wind no change
- SST no change
- Chl hint increase
Results suggests the pelagic niche for the Adelie is changing
Timing of the sea ice extent
Enhanced productivity is associated with the warm upwelled water.
Using Bill’s radio-tagged penguins define the kernel foraging and relate to the remote sensing data base

<table>
<thead>
<tr>
<th>Sea Ice Coverage (%)</th>
<th>SST (°C)</th>
<th>Chlorophyll (mg/m³)</th>
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</thead>
<tbody>
<tr>
<td>0 - 27%</td>
<td>-0.2 - 2</td>
<td>0.07 - 2.4</td>
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</table>
Glider Operations for 2009-2010 field season

5 gliders in 2010 (& 1 in Amudsen and 2 in ROSS):

- 1000 m meter glider, outfitted with CTD/backscatter/fluorescence
  2 missions: First glider to be deployed in late November, fly to Rothera from Palmer. Survey will be looking for warm ACC water

- Four 200 m gliders. One glider outfitted with CTD, backscatter, chlorophyll and CDOM fluorescence. They will survey the canyon area prior to the RV gould arrival. The FIRE glider will be deployed at Palmer. As well as the ADCP glider. We will also add a REMUS (coming). One on the Gould.
REMUS-100

• CTD
• ADCP
• Altimeter
• Fluorometer

Moline SEGR: REMUS addition to Palmer efforts
REMUS will provide high resolution volumetric data out over the canyon.
OOI planning & prosecution

cyberinfrastructure
What is like working at sea?
We leave from Patagonia in southern Chile
Move onto ship

Unpack supplies and build lab

Tie everything down

Build water equipment
The crossing is about four days, it is usually rough so you can’t work outside. Alot of the people usually do not feel good.
Welcome to Palmer Station
Living at station you work all the time, but the scenery and local animals are fun and not scared of humans.
When ships starts sampling stations instruments are lowered each time. They are controlled from the ship.
Water is collected, samples are then filtered for later biochemical analysis and some samples are incubated to provide a set of measurements.
Nets are deployed to catch animals
Moorings and sediment traps are deployed.
Good bye my friend,
I hope you come back